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THE ECONOMIC PECULIARITIES OF THE CONSTRUCTION OF SMALL HYDROELECTRIC PLANTS

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Introduction. The efficient use of energy from small water flows is important from the point of view of saving fuel, and energy resources, and protecting the environment[1]. It should be noted that many developed countries of the world are building and using mini-HPPs. This fact becomes even more important in the RA as it is a country with poor fuel and energy resources. It is necessary to use every opportunity effectively, to draw up a development plan towards energy security and independency and implement it step by step. It is necessary to solve this issue at the state level by creating an appropriate professional commission.

The relevance of the article. The creation of several mini-HPPs will provide an opportunity to obtain additional electrical energy, and to alleviate the energy challenges to some extent.

Purpose. The purpose of the article is to study the necessity of building a mini-HPP station in the RA Aragatsont region and to make appropriate proposals.

Literature review. The proper management of water resources has an undeniable importance in terms of providing electricity in the country. There are practically no energy/fuel resources in the RA, and water power plants are considered one of the primary sources of electricity for the RA[2][3]. According to the Water Code of the RA, water resources are the sum of national water supplies and usable water sources. National water resources are the sum of the quantity and quality of water resources needed to meet basic human needs and maintain aquatic ecosystems[4].

The rivers of the Republic of Armenia, as a rule, have special characteristics of mountain rivers: large declines and slopes, waterfalls and slides, flood-mud temporary

[1] Papikyan S.R. New economic approaches to the development of hydroelectric power stations in Armenia. // Russia: trends and development prospects. Yearbook. Issue 17, part 2. Materials of the XIII International Scientific and Practical Conference, Regions of Russia: development strategies and mechanisms for the implementation of priority national and regional projects and programs, Part 2./ M, 2022. 309-311.

[2] Butysin A.V. Impact of hydroelectric power plants on the environment. // Advances in modern natural science. – 2011. – No. 7. – P. 84-85.

[3] Source: www.minenergy.ampage/448, last accessed: 15/10/2023.

[4] RA Water Code, Number HO-373-N, RAPT 2002.07.10/24(199) Article 581, Adopted by the National Assembly of the Republic of Armenia on June 4, 2002, Chapter 1, Article 1.

rivers and beds, rainwater, snowmelt and underground feeding, and spring floods. It is particularly noteworthy that the flow mainly occurs in high-altitude zones[1].

In the RA, according to the nature of utilization, two main types of rivers merge - irrigation and electricity. For rational use of water for irrigation, reservoirs were built on the rivers, the number of which reaches 80 with a total area of 990 million m^3. They are used mainly for irrigation, energy, and fish farming purposes. The largest of the reservoirs is Akhuryan with a volume of 525 million m^3 (Turkey also uses these water reserves). The use of the RA rivers for energy purposes is also evidenced by the existing hydroelectric power plants (HPP) in RA. The most famous of them are the Sevan-Hazdan cascade (6 HHP), and Vorotan cascade (3 HHP).

From the point of view of water resources management, the construction of HPPs is important[2].

Methodology. The main hydraulic equations and energy balance conditions for energy storage and conversion, design, and construction of hydroelectric power plants were used in the framework of this research.

Analyses and discussion. The mini-HPP is planned to be built in the Aragatsotn region, in the territory of the Aragats community. A water intake is built on its left side. The total length of the derivation is 3682.0m, which currently exists and was previously made of steel pipes with a diameter of 0.15m. The capacity of the derivation is 0.025m^3/s.

The existing HPP building is of the above-ground type, where it is planned to install one hydro unit consisting of a turbine and a chrono-generator. A bridge crane with a lifting capacity of 1.0 tonnes will be installed in the HPP building. The foundations of hydro units will be made of reinforced concrete. The axis of the hydroturbine is 1943.0m. The water used by the HPP is removed through a rectangular drainage channel.

HPP-standard parameters are:

- installed capacity: N = 23 kW;
- static pressure: Hs = 175.4m;
- calculated pressure: H = 115.5m;
- calculated output: Q = 0.025m^3/s;

The average annual amount of produced electricity is 0.18 million kWh.

Capital investments aimed at the restoration of irrigation systems should ensure priority repair or restoration of the main irrigation canals in areas where gravity water

[1] Concept of "Introduction of water-saving technologies", Appendix No. 1 of the RA Government's decision No. 39-L of January 17, 2019

[2] Volnushkina K. A. Bryanskaya Yu. V. // Hydraulic resistance of pipelines restored using polymer hoses. // Hydraulic engineering. No. 9, 2023.

supply is not possible by upgrading pumping stations, intending to increase the water capacity of the canals by construction or reconstruction of internally operated canals[1].

The correct management of water resources is also important in terms of providing electricity in the country. There are practically no energy resources in the RA and hydropower resources are considered to be one of Armenia's sources of electricity[2].

The Gegharot River is the right tributary of the Kasakh River, which flows 47 kilometers from the mouth of the River. The length of the river is 25km. It originates from Aragats Mountain and flows in both east and northeast directions. The catchment area is 66.0 km^2, and the average height of the catchment basin is 2970m. It originates from the 4090m height of the eastern slope of Aragats mountain. The source forms a small water catchment area, covered with eternal snow. In the upper reaches, the river mainly flows through the gorge, on the way it receives numerous springs and streams fed by snowmelt.

The planned HPP should fully utilize the hydropower reserves between 2118.4 meters and 1943.0 meters of the river as much as possible. Based on the average monthly data of the annual flow of 50% safety in the given section of the river and the size of the necessary environmental output, let's choose the main parameters of the HPP.

By derivation, the important energy parameters of the HPP are calculated output, calculated pressure, and installed capacity[3].

To implement the pipeline derivation, consider the efficiency of investments in the case of pipelines of different diameters.

Pressure losses in the pipeline were calculated according to the following formula:

$$h_w = 1.1 \cdot aAQ^2L,$$

where:

A is the resistivity of the pipe;

Q is output; L is the length of the pipeline;

1.1 is a factor by which local losses are considered;

a is a correction factor / when the water speed is greater than 1.2 m/s, then a=1/.

Let's determine the values of the parameters of the HPP by technical-economic calculation, taking into account the environmental outputs. The amount of technical losses of electricity is accepted as 4%.

The calculation results are presented in Table 1.

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[1] Hakobyan E.A. Existing problems in the field of irrigation and ways of solving them // Current problems of socio-economic development in the Republic of Armenia/Scientific articles collection/, book 2, 2013, -224 pages: Pages 150-152 :

[2] National Adaptation Program for the Advancement of Medium and Long-Term Adaptation Planning in Armenia, UNDP-KPC Project, "Identification and Analysis of Legal, Institutional, Vulnerability Assessment and Adaptation Planning Gaps and Obstacles in the Fields of Water Resource Management under Climate Change Conditions", 2020. Page 14.

Table 1

The calculation of HPP parameters
a/ when the pipeline diameter is 0.15 m

Output, m^3/s	0.015	0.020	0.025	0.030	0.035
Static pressure, m	175.4				
Calculated pressure, m	1583.8	137.0	115.5	89.1	60.0
Power, kW	18.0	22.0	23.0	21.0	16.0
Electricity output, million kWh	0.15	0.17	0.18	0.17	0.13
Amount of electric energy sold, million kWh	0.14	0.16	0.17	0.1	0.12
Capital investments, million AMD	10.2	11.0	11.3	11.0	9.6
Internal rate of profit, %	8.5	12.88	14.15	12.1	4.9
Investment payback period, year	10.7	7.6	6.9	8.0	15.6

From the data of the table can be concluded that the version of the pipeline with a diameter of d=0.15m and output Q=0.025m^3/s has the best economic indicators (IRR=14.15%, PB=6.9 years). This option is accepted as a draft project, in which case the parameters of the HPP will be:

- installed power: N=23KW,
- calculation output: Q=0.025m^3/s,
- static pressure: Hu=175.4m,
- calculated pressure: H=115.5m.

It is planned to install one hydro unit in the HPP building, which will have an automatic regulation and control system. The control, automation, and control station equipment ensures the normal operation of the station in automatic mode.

A separate location inside the HPP building is provided for all control panels of the HPP. The tower block also fits into the building.

In this case, there is a need to have a telephone connection between the HPP operating staff and the district operating service, because the HPP is connected to a substation belonging to the power system. Anti-fire measures are planned in the HPP building. In the vertical section of the hydroelectric power plant-intake receiver, the studies of geologic hydrology and regimes show that taking into account the ecological requirements, the quantities of water flow resources used for the hydroelectric power plant are guaranteed and reliable.

Based on these data, a water management calculation for the 50% security accounting year was made in Table 2 for the considered versions of the HPP, where the sanitary outputs were taken into account. The magnitude of the potential flow for the use of the hydroelectric power plant and the electric power output have been determined.

The suitability of the site selection of the HPP structures lies in the fact that there are currently existing wall water intakes, derivation pipelines, and HPP building structures.

HPP includes the following main structures:

1. Dam water intake;
2. Pressure derivation pipeline;
3. Hydroelectric power plant.

The HPP dam water intake, which exists, was built in the 2118.4m section of the Gegharot River. A water intake was built on the river's left side.

The total length of the derivation is 3682.0m, which currently exists and was previously made of steel pipes with a diameter of 0.15m. The capacity of the derivation is 0.025m^3/s. It should be noted that currently, HPP produces about 1/3 of the electricity of RA[1].

The water used by the HPP is removed through a rectangular drainage channel. The minimum environmental output is 320 l/s. The calculated output of the HPP is taken from the pressure pipeline starting from the dam intake, and after the HPP building, it is returned to the river, without any change in quality or quantity. As a result, the regime of existing water consumers is not violated. No need for felling trees during construction. Wildlife is absent here, as it is located next to an existing road.

[1] Papikyan S.R., Energy of Armenia: Today and Tomorrow. // Energy abroad. M. No. 4; 2022, pp. 42-45.

Table 2

An estimate of the annual average multi-year magnitude of produced electricity

Indicator	Months												Year Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Month average natural water output (m^3/s)	0,36	0,36	0,38	0,46	0,88	2,67	3,17	1,95	0,66	0,50	0,44	0,42	1,02
Sanitary outlet volume (m^3/s)	0,11	0,10	0,11	0,17	0,29	0,28	0,32	0,22	0,18	0,13	0,14	0,12	-
Free flow (m^3/s)	0,25	0,26	0,27	0,29	0,59	2,39	2,85	1,73	0,48	0,37	0,30	0,30	
The necessary output volume for HPP (m^3/s)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
Static pressure (m)	175,40	175,40	175,40	175,40	175,40	175,40	175,40	175,40	175,40	175,40	175,40	175,40	
Pressure (m)	115,50	115,50	115,50	115,50	115,50	115,50	115,50	115,50	115,50	115,50	115,50	115,50	
The energy efficiency of aggregates	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	0,81	
HPP capacity (kW)	23	23	23	23	23	23	23	23	23	23	23	23	
Working hours	744	672	744	720	744	720	744	744	720	744	720	720	8 736
Amount of produced energy (approx. kWh)	17	15	17	17	17	17	17	0	17	17	17	17	180

The construction of HPP can contribute to the solution of energy security issues to some extent[1].

The annual operating costs of power generation are made up of depreciation allocations (assumed to be linear at 3.3% of the budgeted cost), repair costs, staff salaries, administrative costs, and material procurement costs.

Table 3

Cost efficiency forecasting (AMD)

Total output, kWh	183 230,4
Own needs (2%) and transportation loss (2%)	175 901,1
Gross income (kWh *tariff) thousand. AMD	**4 197 001,3**
Operating salary	1 256 989,7
Operating costs, routine repairs, and breakdowns	576 252,4
Net income	**2 363 759,3**
Administrative salary	-
Administrative expenses	**240 000,0**
Fees and other mandatory fees	180 000,0
Amortization allocations (30 years, on full capital)	376 128,7
Water transportation costs	-
Other expenses	4 200,0
Profit before taxes	1 563 430,6
Profit tax	312 686,1
Net profit	**1 250 744,5**

The capital investments necessary for the construction and installation of HPP are presented in detail in Table 4.

Table 4

Capital investments of HPP

Construction	AMD
Dam	2 600,00
Pipeline	240 311,55
HPP building	747 000,00
The cost of hydro units (hydro turbines, generators) with installation	6 037 500,00
Transformer substation	410 550,00
High voltage power line	445 900,00
Other expenses	
Total for construction	7 883 861,55

[1] Papikyan S.R., Ways to increase energy security and efficiency, Monograph: National Academy of Sciences, 2023, 100 pages.

Fuel	800 000,00
Design and estimate works	1 000 000,00
Other expenses	1 600 000,00
Total other expenses	3 400 000,00
Total investments	**11 283 862**

Scientific novelty. As a result of the conducted studies and analyses, the feasibility of building a mini-HPP in the area of Aragats community in the Aragattsotn region of the RA was assessed, providing saving of fuel and energy resources, which can reach up to 40 tons of saved fuel resources per year.

Practical implications. The research has practical significance and can be applied both in the Aragatsotn region and in other similar territories of RA.

Conclusions:

1. Studies show that the construction of mini-HPP is profitable and technically feasible. In the case of the proposed plan, the HPP will produce more than 180,000 KW/hour of electricity annually.
2. Fuel saving can be more than 40 tons per year. In the process, no more than 360 kilograms of nitrogen oxides and other toxic substances will be released into the environment.
3. The results of the article can be used specifically for the efficient use of small water streams.

References

1. Butysin A.V. Impact of hydroelectric power plants on the environment. // Advances in modern natural science. – 2011. – No. 7. – P. 84-85.
2. Concept of "Introduction of water-saving technologies", Appendix No. 1 of the RA Government's decision No. 39-L of January 17, 2019
3. Hakobyan E.A. Existing problems in the field of irrigation and ways of solving them // Current problems of socio-economic development in the Republic of Armenia/Scientific articles collection/, book 2, 2013, -224 pages: Pages 150-152
4. National Adaptation Program for the Advancement of Medium and Long-Term Adaptation Planning in Armenia, UNDP-KPC Project, "Identification and Analysis of Legal, Institutional, Vulnerability Assessment and Adaptation Planning Gaps and Obstacles in the Fields of Water Resource Management under Climate Change Conditions", 2020. Page 14.
5. Papikyan S.R., Energy of Armenia: Today and Tomorrow. // Energy abroad. M. No. 4; 2022, pp. 42-45.
6. Papikyan S.R. New economic approaches to the development of hydroelectric power stations in Armenia. // Russia: trends and development prospects. Yearbook.

Issue 17, part 2. Materials of the XIII International Scientific and Practical Conference, Regions of Russia: development strategies and mechanisms for the implementation of priority national and regional projects and programs, Part 2./ M, 2022. 309-311.
7. Papikyan S.R., Ways to increase energy security and efficiency, Monograph: National Academy of Sciences, 2023, 100 pages.
8. RA Water Code, Number HO-373-N, RAPT 2002.07.10/24(199) Article 581, Adopted by the National Assembly of the Republic of Armenia on June 4, 2002, Chapter 1, Article 1.
9. Volnushkina K. A. Bryanskaya Yu. V. // Hydraulic resistance of pipelines restored using polymer hoses. // Hydraulic engineering. No. 9, 2023.
10. www.minenergy.ampage/448

ՓՈՔՐ ՀԻԴՐՈԷԼԵԿՏՐԱԿԱՅԱՆՆԵՐԻ ԿԱՌՈՒՑՄԱՆ ՏՆՏԵՍԱԳԻՏԱԿԱՆ ԱՌԱՆՁՆԱՀԱՏԿՈՒԹՅՈՒՆՆԵՐԸ

Ստեփան Ռաֆիկի Պապիկյան
Մանուկ Ռաֆիկի Պապիկյան

Համառոտագիր: Ներածություն: Վառելիքաէներգետիկ ռեսուրսների խնայողության,շրջակա միջավայրի պահպանության տեսակետից կարևոր նշանակություն ունի փոքր ջրհոսքերի էներգիայի արդյունավետ օգտագործումը: Հարկ է նշել, որ աշխարհի զարգացած շատ երկրներում ներկայումս կառուցում և օգտագործում են մինի հիդրոէլեկտրակայաններ: Այս հանգամանքը ավելի է կարևորում, երբ Հայաստանն աղքատ է վառելիքաէներգետիկ ռեսուրսներով: Այն բերում ենք դրսից հաղթահարելով բազմաթիվ դժվարություններ և խութեր: Մեր տարածաշրջանում տեղի ունեցող բարդ աշխարհաքաղաքական զարգացումներն այս առումով մեզ մտորելու տեղիք է տալիս: Յուրաքանչյուր հնարավորություն անհրաժեշտ է արդյունավետ է օգտագործել: Անհրաժեշտ է կազմել զարգացման ծրագիր և փուլ առ փուլ իրականացնել: Այս հարցում մանրուքներ լինել չեն կարող: Այս հարցը անհրաժեշտ է լուծել պետական մակարդակով ստեղծելով համապատասխան մասնագիտական հանձնաժողով: Արդյունքները երկար սպասեցնել չեն տա:

Արդիականությունը: Մի քանի տասնյակ ԿՎտ մինի ՀԷԿ-երի ստեղծումը հնարավորություն կտա ստանալ լրացուցիչ էլեկտրական էներգիա,որոշ չափով մեղմացնել էներգետիկ մարտահրավերները:

Նպատակը: Հոդվածի նպատակն է ուսումնասիրել ՀՀ Արագածոտնի մարզում, Արագած համայնքի տարածքում մինի հիդրոէլեկտրակայան կառուցելու անհրաժեշտությունը և կատարել համապատասխան առաջարկներ:

Մեթոդաբանություն: Սույն հետազոտության շրջանակներում օգտագործվել են էներգիայի պահպանման և փոխակերպման, հիդրոէլեկտրակայանների նա-

խագծման և կառուցման հիմնական հիդրավլիկական հավասարումները և էներգետիկ հաշվեկշռի պայմանները:

Կիրառման հնարավորությունները: Աշխատանքն ունի գործնական նշանակություն և կարող է կիրառվել ինչպես Արագածոտնի մարզում,այնպես էլ ՀՀ բոլոր տարածքներում:

Գիտական նորույթը: Կատարված ուսումնասիրությունների և վերլուծությունների արդյունքում գնահատվել է ՀՀ Արագածոտնի մարզում, Արագած համայնքի տարածքում մինի հիդրոէլեկտրակայան կառուցելու նպատակահարմարությունը ապահովելով վառելիքաէներգետիկ ռեսուրսների խնայողություն, որը տարեկան կարող է կազմել մինչև 40 տոննա վառելիք:

Բանալի բառեր. հիդրոէլեկտրակայան, էլեկտրաէներգիա, հոսակորուստ, խողովակաշար, հզորություն, խողովակ, կապիտալ ներդրումներ, հաշվային ճնշում:

ЭКОНОМИЧЕСКИЕ ОСОБЕННОСТИ СТРОИТЕЛЬСТВА МАЛЫХ ГЭС

Степан Рафикович Папикян
Манук Рафикович Папикян

Аннотация. Введение. С точки зрения экономии топливно-энергетических ресурсов и защиты окружающей среды - большое значение имеет эффективное использование энергии малых водных потоков. Следует отметить, что многие развитые страны мира в настоящее время строят и эксплуатируют мини-ГЭС. Это обстоятельство становится еще более важным в связи с тем, что Армения бедна топливно-энергетическими ресурсами. Мы приносим его извне, преодолевая множество трудностей и препятствий. Сложные геополитические события, происходящие в нашем регионе, дают нам повод задуматься об этом. Любую возможность необходимо использовать эффективно. Необходимо составить план развития и поэтапно его реализовать. Никаких мелочей в этом вопросе быть не может. Необходимо решить этот вопрос путем создания соответствующей профессиональной комиссии на государственном уровне. Результаты не заставят себя долго ждать.

Актуальность. Создание нескольких десятков киловатт мини-ГЭС даст возможность получать дополнительную электрическую энергию, в некоторой степени смягчит энергетические задачи.

Цель статьи – изучить необходимость строительства мини-ГЭС в общине Арагац Арагацотнского района РА и внести соответствующие предложения.

Методология. В работе использованы основные гидравлические уравнения и условия энергетического баланса для хранения и преобразования энергии, проектирования и строительства гидроэлектростанций.

Возможности применения. Работа имеет практическое значение и может быть применена как в Арагацотнском регионе, так и на всей территории РА.

Научная новизна. В результате проведенных исследований и анализов оценена целесообразность строительства мини-ГЭС на территории общины Арагац Арагацотнского района Республики Армения, обеспечивающей экономию до 40 тонн топливно-энергетических ресурсов в год.

Ключевые слова: ГЭС, электроэнергия, потери расхода, трубопровод, мощность, труба, капитальные вложения, давление.

THE ECONOMIC PECULIARITIES OF CONSTRUCTION OF SMALL HYDROELECTRIC PLANTS

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Abstract. Introduction. The efficient use of energy from small water flows is important from the point of view of saving fuel, and energy resources, and protecting the environment. It should be noted that many developed countries of the world are building and using mini-HPPs. This fact becomes even more important in the RA as it is a country with poor fuel and energy resources. It is necessary to use every opportunity effectively, to draw up a development plan towards energy security and independency and implement it step by step. It is necessary to solve this issue at the state level by creating an appropriate professional commission.

The relevance of the article. The creation of several mini-HPPs will provide an opportunity to obtain additional electrical energy, and to alleviate the energy challenges to some extent.

Purpose. The purpose of the article is to study the necessity of building a mini-HPP station in the RA Aragatsont region and to make appropriate proposals.

Methodology. The main hydraulic equations and energy balance conditions for energy storage and conversion, design, and construction of hydroelectric power plants were used in the framework of this research.

Practical implications. The research has practical significance and can be applied both in the Aragatsotn region and in other similar territories of RA.

Scientific novelty. As a result of the conducted studies and analyses, the feasibility of building a mini-HPP in the area of Aragats community in the Aragattsotn region of the RA was assessed, providing saving of fuel and energy resources, which can reach up to 40 tons of saved fuel resources per year.

Keywords: HPP, electricity, water loss, pipeline, capacity, capital investment, pressure.